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Search for supersymmetry in final states with photons and missing transverse momentum in proton-proton collisions at 13 TeV

The CMS Collaboration*

Abstract

Results are reported for a search for supersymmetry in final states with photons and missing transverse momentum in proton-proton collisions at the LHC. The data sample corresponds to an integrated luminosity of 35.9 fb^{-1} collected at a center-of-mass energy of 13 TeV using the CMS detector. The results are interpreted in the context of models of gauge-mediated supersymmetry breaking. Production cross section limits are set on gluino and squark pair production in this framework. Gluino masses below 1.86 TeV and squark masses below 1.59 TeV are excluded at 95% confidence level.

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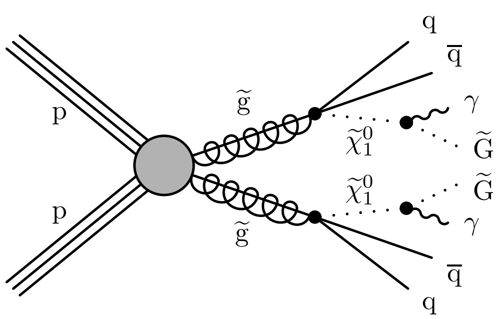
*See Appendix A for the list of collaboration members

1 Introduction

One of the primary goals of the CMS experiment at the CERN LHC is to search for physics beyond the standard model (SM). Supersymmetry (SUSY) [1–6] is an extension that provides explanations for several outstanding issues with the SM. In particular, SUSY addresses the large quantum corrections to the mass term in the Higgs potential and provides a viable dark matter candidate [7]. Models with general gauge-mediated (GGM) SUSY breaking [8–15] have the additional benefit of naturally suppressing flavor violations in the SUSY sector. GGM models can have a wide range of features but typically result in final states that include the gravitino ($\widetilde{\mathrm{G}}$) as the lightest supersymmetric particle (LSP). The next-to-lightest supersymmetric particle (NLSP) in these models is often taken to be a neutralino ($\widetilde{\chi}^0_1$). The conservation of R parity [16] implies that the gravitino is stable and remains undetected. Therefore, proton-proton (pp) collisions that produce SUSY particles will have an imbalance in the total observed transverse momentum, referred to as missing transverse momentum $\vec{p}_{\mathrm{T}}^{\text{miss}}$ and defined as the negative vector sum of the transverse momenta of all visible particles in an event. Its magnitude is referred to as $p_{\mathrm{T}}^{\text{miss}}$. If the NLSP is bino-like, its primary decay will be to a gravitino and a photon (γ), resulting in final states with significant missing transverse momentum and one or more photons.

This paper presents a search for GGM SUSY in final states involving two photons and missing transverse momentum. The data sample, corresponding to an integrated luminosity of $35.9\,\mathrm{fb}^{-1}$ of ppcollisions at a center-of-mass energy $\sqrt{s} = 13\,\mathrm{TeV}$, was collected with the CMS detector in 2016. The analysis described here achieves a substantial improvement in sensitivity compared to the search performed by the CMS Collaboration on the smaller 2015 data set [17] and is comparable in sensitivity to similar searches from the ATLAS Collaboration [18, 19].

Two simplified model frameworks [20–24] are used for the interpretation of the results. The T5gg model assumes gluino ($\widetilde{\mathrm{g}}$) pair production and the T6gg model assumes squark ($\widetilde{\mathrm{q}}$) pair production. The models assume a 100% branching fraction for the gluinos and squarks to decay as shown in Fig. 1. The squarks in the T6gg model can be either first or second generation. We assume a 100% branching fraction for the NLSP neutralino to decay to a nearly massless gravitino and a photon, $\widetilde{\chi}^0_1 \to \widetilde{\mathrm{G}}\gamma$, resulting in characteristic events with large $p_{\mathrm{T}}^{\text{miss}}$ and two photons.



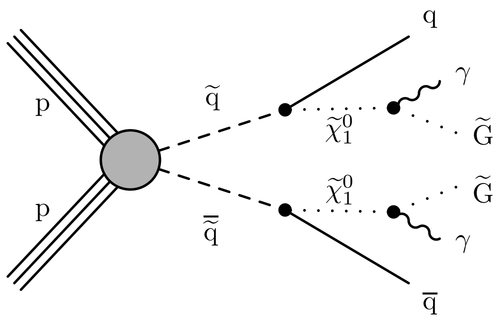


Figure 1: Diagrams showing the production of signal events in the collision of two protons (p). In gluino ($\widetilde{\mathrm{g}}$) pair production in the T5gg simplified model (left), the gluino decays to a quark-antiquark pair ($\mathrm{q}\overline{\mathrm{q}}$) and a neutralino ($\widetilde{\chi}^0_1$). In squark ($\widetilde{\mathrm{q}}$) pair production in the T6gg simplified model (right), the squark decays to a quark and a neutralino. In both cases, the neutralino subsequently decays to a photon (γ) and a gravitino ($\widetilde{\mathrm{G}}$).

Standard model processes such as direct diphoton production or events with jets produced through the strong interaction, referred to as quantum chromodynamics (QCD) multijet events, can result in events with two photons. If the hadronic activity in the event is poorly measured, these processes can mimic the signal topology even though they lack genuine $p_{\mathrm{T}}^{\mathrm{miss}}$. For the case of QCD multijet events, there may be real photons in the event, or jets rich in electromagnetic (EM) energy that are misreconstructed as photons. Events with genuine $p_{\mathrm{T}}^{\mathrm{miss}}$ also contribute to the composition of the candidate sample. These events are mainly from Wγ and W+jet(s) production, where an electron is misidentified as a photon in $\mathrm{W} \to \mathrm{e}\nu$ decays. A smaller background arises from Z$\gamma\gamma$ events where the Z boson decays to two neutrinos, $\mathrm{Z} \to \nu\bar{\nu}$.

2 Detector, data, and simulated samples

The central feature of the CMS apparatus is a superconducting solenoid of 6 m internal diameter, providing a magnetic field of 3.8 T. Within the solenoid volume are a silicon pixel and strip tracker covering the pseudorapidity region $|\eta| < 2.5$, as well as a lead tungstate crystal electromagnetic calorimeter (ECAL), and a brass and scintillator hadron calorimeter (HCAL), each composed of a barrel and two endcap regions and covering the range $|\eta| < 3.0$. Forward calorimeters extend the coverage up to $|\eta| < 5.0$. Muons are measured in gas-ionization detectors embedded in the steel flux-return yoke outside the solenoid and cover the range $|\eta| < 2.4$. A more detailed description of the CMS detector, together with a definition of the coordinate system used and the relevant kinematic variables, can be found in Ref. [25].

Events of interest are selected using a two-tiered trigger system [26]. The first level is composed of custom hardware processors and uses information from the calorimeters and muon detectors to select events at a rate of around 100 kHz. The second level, known as the high-level trigger, consists of a farm of processors running a version of the full event reconstruction software optimized for fast processing. This trigger reduces the event rate to around 1 kHz before data storage. This analysis used a diphoton trigger to collect the data. The trigger requires a leading (subleading) photon with transverse momentum $p_{\mathrm{T}} > 30$ (18) GeV, and a combined invariant mass $m_{\gamma\gamma} > 95$ GeV. The photons are also required to pass isolation and cluster shape requirements.

Monte Carlo (MC) simulations are used for several purposes in this analysis. Simulations of the signal processes are used to determine signal efficiencies; background process simulation is used for validation of the analysis performance and to model the contribution from $\mathrm{Z}\gamma\gamma \to \nu\bar{\nu}\gamma\gamma$ events. The event generator MADGRAPH5_aMC@NLO 2.3.3 [27] is used to simulate the signal samples at leading order. The background samples are generated at next-to-leading order using MADGRAPH5_aMC@NLO 2.4.2. For both signal and background processes, the parton showering, hadronization, SUSY particle decays, multiple-parton interactions, and the underlying event are described by the PYTHIA 8.212 [28] program with the CUETP8M1 [29] generator tune. The signal samples are generated with either two gluinos or two squarks and up to two additional partons in the matrix element calculation. The parton distribution functions (PDFs) are obtained from the NNPDF3.0 [30] set. For the background processes, the detector response is simulated using GEANT4 [31], while the CMS fast simulation [32, 33] is used for the signal events. For both signal and background simulated events, additional pp interactions (pileup) are generated with PYTHIA and superimposed on the primary collision process. The simulated events are reweighted to match the pileup distribution observed in data.

The signal events were generated using the T5gg and T6gg simplified models and are characterized by the masses of the particles in the decay chain. For the gluino (squark) mass we simulate a range of values from 1.4 to 2.5 (1.2 to 2.0) TeV in steps of 50 GeV. These mass ranges were selected to overlap and expand upon the mass ranges excluded by previous searches [17, 18].

The neutralino masses range from 10 GeV up to the mass of the gluino or squark. The cross sections are calculated at next-to-leading-order (NLO) accuracy including the resummation of soft gluon emission at next-to-leading-logarithmic (NLL) accuracy [34–38], with all the unconsidered sparticles assumed to be heavy and decoupled. The uncertainties in the cross sections are calculated as described in Ref. [39].

3 Event selection

Photon, electron, muon, charged and neutral hadron candidates are reconstructed with the particle-flow event algorithm [40], which reconstructs particles based on information from all detector subsystems. The energy of photons is directly obtained from the ECAL measurement. The energy of electrons is determined from a combination of the electron momentum at the primary interaction vertex as determined by the tracker, the energy of the corresponding ECAL cluster, and the energy sum of all bremsstrahlung photons spatially compatible with originating from the electron track. The energy of muons is obtained from the curvature of the corresponding track. The energy of charged hadrons is determined from a combination of their momentum measured in the tracker and the matching ECAL and HCAL energy deposits, corrected for zero-suppression effects and for the response function of the calorimeters to hadronic showers. Finally, the energy of neutral hadrons is obtained from the corresponding corrected ECAL and HCAL energy.

Photon candidates are required to satisfy a series of identification criteria to ensure a high purity [41]. The shape of the energy deposit in the ECAL must be consistent with that of an EM shower, and the amount of energy present in the corresponding region of the HCAL must not exceed 5% of the ECAL energy, since EM showers are expected to be contained almost entirely within the ECAL. To ensure high trigger efficiency, we require all photons to satisfy $p_{\mathrm{T}} > 40\,\mathrm{GeV}$. Because the SUSY signal models used in this analysis produce photons primarily in the central region of the detector and because the magnitude of the background increases considerably at high $|\eta|$, we consider only photons within the barrel fiducial region of the detector ($|\eta| < 1.44$).

To suppress quark and gluon jets that mimic photons, photon candidates are required to be isolated from other reconstructed particles. Separate requirements are made on the scalar p_{T} sums of charged and neutral hadrons and EM objects in a cone of radius $\Delta R \equiv \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} \equiv 0.3$ around the photon candidate. Each p_{T} sum is corrected for the effect of pileup, and in each case the momentum of the photon candidate itself is excluded. We further require that the photon candidate has no pixel detector track seed, to distinguish the candidate from an electron.

For the purpose of defining the various control regions used in the analysis, we apply an additional set of selection criteria. A misidentified "fake" photon (f) is defined as a photon candidate that satisfies looser requirements on photon isolation and neutral-hadron isolation and fails either the shape requirement for the ECAL clusters or the charged-hadron isolation requirement. In order to ensure that misidentified photons do not differ too much from our photon selection, upper limits are applied to both the charged-hadron isolation and cluster shape requirements. Importantly, because of the large amount of hadronic activity expected in our SUSY signal events, it is possible that real photons from the decay of a neutralino could fail the charged-hadron isolation requirement and therefore fall into the misidentified photon category. In order to avoid this potential signal contamination from SUSY events in the control regions, we additionally require that misidentified photons satisfy $R_9 < 0.9$, where R_9 is defined as the ratio of the energy deposited in a 3$\times$3 array of ECAL crystals to the total energy in the cluster [41]. Real photons have values of R_9 close to unity, so by requiring $R_9 < 0.9$ we ensure that real photons from a possible SUSY signal will not enter our control regions.

Because of the similarity of the ECAL response to electrons and photons, $Z \to ee$ events are used to measure the photon identification efficiency. The selection of electron candidates is identical to that of photons, with the exception that the candidate is required to be matched to a pixel detector seed consistent with a track, to ensure that the electron selection is orthogonal to that of photons. The photon efficiency is measured via the tag-and-probe method [41]. The ratio of the observed to simulated efficiency is found to be consistent with unity and independent of p_T and η. The efficiency of the pixel detector seed veto for photons is measured in $Z \to \mu\mu\gamma$ events and is found to agree between data and simulation.

Events are then assigned to one of four mutually exclusive categories depending on the selection of their highest p_T EM objects: $\gamma\gamma$, ee, ff, and eγ. The two EM objects are required to be separated by $\Delta R > 0.6$. Finally, because of the trigger requirements described in Section 2, the invariant mass of the two EM objects is required to be greater than 105 GeV.

In addition to the requirements already described, any event with a muon satisfying $p_T > 25$ GeV and $|\eta| < 2.4$ as well as track quality and isolation requirements is vetoed. Similarly, we veto events with any additional electrons satisfying $p_T > 25$ GeV, $|\eta| < 2.5$, and signal shape and isolation requirements.

Events in the candidate $\gamma\gamma$ sample are divided into the low-p_T^{miss} control region ($p_T^{miss} < 100$ GeV) and the high-p_T^{miss} signal region ($p_T^{miss} > 100$ GeV). The signal region is further divided into six p_T^{miss} bins that were chosen such that there is a sufficient number of events from the ff control sample in each bin.

4 Estimation of backgrounds

QCD processes such as multijet production can emulate the signal topology and contribute to the background of this analysis. The p_T^{miss} in these processes is not genuine but comes from mismeasurement of the hadronic activity in the event. A second background arises from electroweak (EWK) processes that have genuine p_T^{miss} from the production of neutrinos. There is also a small contribution from $Z\gamma\gamma \to \gamma\gamma\nu\bar{\nu}$ events. This process includes genuine p_T^{miss} and two real photons in the final state.

The contribution from the QCD background is estimated from the observed data using the ff control sample. The ratio of the event yield in the candidate $\gamma\gamma$ sample to that in the ff sample is constructed as a function of p_T^{miss}. More ff events are observed at high p_T^{miss} relative to the $\gamma\gamma$ sample. We model this p_T^{miss} dependence by fitting the ratio to an exponential function in the $p_T^{miss} < 100$ GeV control region. The predicted number of QCD background events in each p_T^{miss} bin in the signal region is then given by this function multiplied by the number of ff events seen in that bin.

In order to set a systematic uncertainty on the method, we derive a second QCD background prediction by noting that the p_T^{miss} distribution of the ff control sample is dependent on the R_9 requirement on the misidentified photons. An alternate ff control sample is built using photon candidates that satisfy all of the requirements for misidentified photons as outlined in Section 3, with the exception that the R_9 requirement is reversed. In the $p_T^{miss} < 100$ GeV control region, we perform an exponential fit to the ratio of the event yield in the high-R_9 ff sample to that of the nominal, low-R_9 ff sample. This function represents the correction required to account for the effect of the R_9 selection on the p_T^{miss} distribution. The size of the correction is between 20 and 40% in the $p_{\mathrm{T}}^{\mathrm{miss}} > 100\,\mathrm{GeV}$ signal region. Multiplying the number of low-R_9 ff events observed in the signal region by this function gives a proxy high-R_9 ff sample. For $p_{\mathrm{T}}^{\mathrm{miss}} < 100\,\mathrm{GeV}$, the ratio of the $p_{\mathrm{T}}^{\mathrm{miss}}$ distribution in the $\gamma\gamma$ sample to that of the proxy ff sample is fit to a constant. We multiply this constant value by the proxy ff yield in the signal region to get a second prediction for the QCD background. The two background estimation methods give values that are consistent within the uncertainties.

Several studies were performed to verify the method, including using a mixed-R_9 ff sample with one misidentified photon satisfying $R_9 > 0.9$ and one satisfying $R_9 < 0.9$ to confirm that the exponential fit continues to accurately describe the mixed-R_9 ff to nominal ff ratio in the high-$p_{\mathrm{T}}^{\mathrm{miss}}$ signal region. As an additional check, a control sample with one photon and one misidentified photon was used as a proxy for the $\gamma\gamma$ candidate sample in a closure test of the method.

Another background for this analysis comes from EWK processes with genuine $p_{\mathrm{T}}^{\mathrm{miss}}$. This background primarily involves Wγ and W+jets events where the W decays to an electron and a neutrino and the electron is misidentified as photon. This leads to final states with photons and significant $p_{\mathrm{T}}^{\mathrm{miss}}$. To obtain an estimate of the EWK background in the signal region, the rate at which electrons are misidentified as photons ($f_{\mathrm{e}\to\gamma}$) is calculated by comparing the mass peak from the Z boson in the ee control sample with the mass peak in the eγ control sample. The mass peak in both samples is modeled using an extended likelihood fit for the signal plus background hypothesis.

The misidentification rate is then given by $f_{\mathrm{e}\to\gamma} = N_{\mathrm{e}\gamma}/(2N_{\mathrm{ee}} + N_{\mathrm{e}\gamma})$, where $N_{\mathrm{e}\gamma}$ and N_{ee} are the signal fit integrals for each sample. The misidentification rate is calculated as a function of several kinematic variables, and a 30% uncertainty is applied to cover any possible dependencies. The final EWK background prediction is given by scaling the number of events in the eγ control sample by the factor $f_{\mathrm{e}\gamma\to\gamma\gamma} = f_{\mathrm{e}\to\gamma}/(1 - f_{\mathrm{e}\to\gamma}) = (2.63 \pm 0.79)\%$.

The irreducible Z$\gamma\gamma$ background is modeled via simulation and is assigned an uncertainty of 50% to cover any potential mismodeling.

5 Sources of systematic uncertainty

Systematic uncertainties are calculated for each contribution to the total background prediction. In addition, systematic uncertainties are assigned for the signal efficiency and the integrated luminosity. The value of each uncertainty and the method used to calculate it are described below.

The largest uncertainties in the background prediction come from uncertainties associated with the QCD background estimate. The magnitude of each uncertainty is shown in Table 1 for the six signal bins. The statistical uncertainty from the ff control sample ranges from 7 to 79% in the signal region. The uncertainty obtained from propagating the errors in the fit parameters to the final prediction is between 2 and 5%. Finally, as described in Section 4, a systematic uncertainty in the fitting procedure is calculated by comparing the primary prediction to the cross check prediction derived using the high-R_9 ff sample. The systematic uncertainty is taken as the difference between the two methods or the uncertainty in that difference, whichever is larger, and ranges between 10 and 83% in the signal region.

Uncertainties in the EWK background prediction include the statistical uncertainty from the eγ control sample and the 30% uncertainty in the rate at which electrons are misidentified as photons. The statistical uncertainty is less than 9% in each of the six signal bins.

Table 1: Event yield and statistical and systematic uncertainties (in numbers of events) in the QCD background estimation for each signal $p_{\mathrm{T}}^{\mathrm{miss}}$ bin.

$p_{\mathrm{T}}^{\mathrm{miss}}$ bin (GeV)	Expected QCD	Stat. uncert.	Fit uncert.	Cross check uncert.
$100-115$	99.0	$+7.2, -6.7$	± 1.8	± 9.9
$115-130$	32.8	$+4.2, -3.7$	± 0.7	± 5.5
$130-150$	18.8	$+3.2, -2.7$	± 0.5	± 4.0
$150-185$	9.9	$+2.3, -1.9$	± 0.3	± 2.8
$185-250$	3.1	$+1.3, -0.9$	± 0.1	± 1.5
≥ 250	1.0	$+0.8, -0.5$	± 0.1	± 0.8

There are also several uncertainties associated with the signal efficiency. The statistical uncertainty from the size of the T5gg or T6gg signal scans ranges from 2 to 44% depending on the mass bin. The PDF uncertainties in the cross sections for signal simulation are between 19 and 35% and are taken from Ref. [39]. Other uncertainties include how well the jet energy scale is known (1 to 30%) and the uncertainty in the photon identification efficiency (2.5%). The uncertainty in the integrated luminosity of the data sample is 2.5% [42].

6 Results

The expected and observed numbers of events for each bin in the signal region prior to the fit described below are shown in Table 2. The full background prediction and the measured $p_{\mathrm{T}}^{\mathrm{miss}}$ distribution are shown in Fig. 2. Notably, in the last bin we observe 12 events and expect $5.4^{+1.6}_{-1.5}$ background events. Taking all six signal bins into account, this corresponds to a significance of 2.4 standard deviations, not considering the look-elsewhere effect. We determine 95% confidence level (CL) upper limits on gluino pair production and squark pair production cross sections.

Table 2: Number of expected background and observed data events in the signal region prior to the fit defined in the text. The uncertainty in each expected background yield includes the statistical uncertainty and all of the systematic uncertainties described in Section 5 added in quadrature.

$p_{\mathrm{T}}^{\mathrm{miss}}$ bin (GeV)	QCD	EWK	$Z\gamma\gamma$	Total background	Observed
$100-115$	99 ± 12	13.7 ± 4.2	1.3 ± 0.6	114 ± 13	105
$115-130$	$32.8^{+7.0}_{-6.7}$	9.0 ± 2.7	1.1 ± 0.6	$42.9^{+7.5}_{-7.3}$	39
$130-150$	$18.8^{+5.1}_{-4.9}$	7.4 ± 2.3	1.1 ± 0.6	$27.3^{+5.6}_{-5.4}$	21
$150-185$	$9.9^{+3.6}_{-3.4}$	6.1 ± 1.9	1.3 ± 0.7	$17.4^{+4.1}_{-3.9}$	21
$185-250$	$3.1^{+1.9}_{-1.7}$	5.8 ± 1.8	1.3 ± 0.6	$10.2^{+2.7}_{-2.6}$	11
≥ 250	$1.0^{+1.1}_{-0.9}$	3.3 ± 1.1	1.1 ± 0.6	$5.4^{+1.6}_{-1.5}$	12

The upper limits are determined using the modified frequentist $\mathrm{CL_s}$ method [43, 44] with an LHC-style profile likelihood ratio as test statistic [45] evaluated in the asymptotic approximation [46]. The likelihood function is constructed from the background and signal $p_{\mathrm{T}}^{\mathrm{miss}}$ distributions across the six bins described in Section 4. The systematic uncertainties described in Section 5 are included in the test statistic as nuisance parameters with log-normal probability distributions. Statistical uncertainties from the limited size of the control samples and the signal MC samples are handled using gamma probability distributions. Several studies were performed to characterize the excess in the final $p_{\mathrm{T}}^{\mathrm{miss}}$ bin and to ensure that the statistical treatment of the data is robust. In particular, the pre- and postfit distributions were checked to make sure that the pulls from the uncertainties are consistent with the expected behavior.

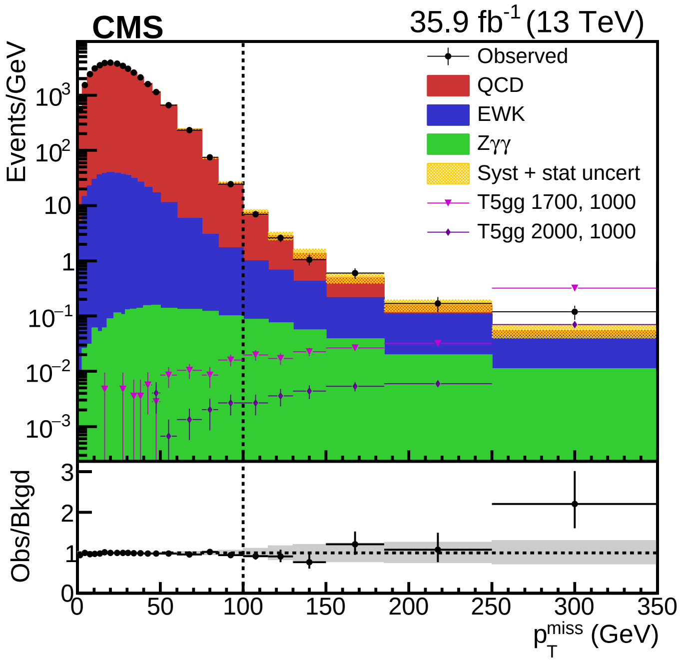


Figure 2: The top panel shows the observed p_T^{miss} distribution in data (black points) and predicted background distributions prior to the fit. The vertical line marks the boundary between the validation region ($p_T^{miss} < 100\,\text{GeV}$) and the signal region ($p_T^{miss} > 100\,\text{GeV}$). The last bin includes all events with $p_T^{miss} > 250\,\text{GeV}$. The QCD background is shown in red, the EWK background is shown in blue, and the $Z\gamma\gamma$ background is shown in green. The p_T^{miss} distribution shown in pink (purple) corresponds to the T5gg simplified model with $m_{\tilde{g}} = 1700\ (2000)\,\text{GeV}$ and $m_{\tilde{\chi}_1^0} = 1000\,\text{GeV}$. The bottom panel shows the ratio of observed events to the expected background. The error bars on the ratio correspond to the statistical uncertainty in the number of observed events. The shaded region corresponds to the total uncertainty in the background estimate.

In Fig. 3 we present 95% CL upper limits on the gluino and squark pair production cross sections as a function of the mass pair values for the two models considered in this analysis, $m_{\tilde{\chi}_1^0}$ versus $m_{\tilde{g}}$ and $m_{\tilde{\chi}_1^0}$ versus $m_{\tilde{q}}$. From the NLO+NLL predicted signal cross sections and their uncertainties we derive contours representing lower limits in the SUSY mass plane. We also show expected limit contours based on the expected experimental cross section limits and their uncertainties. For values of the neutralino mass between 500 and 1500 GeV, we expect to exclude gluino masses up to 2.02 TeV and squark masses up to 1.74 TeV. This is an improvement of approximately 400 and 300 GeV, respectively, upon the reach of the previous CMS result [17]. We observe exclusions for gluino masses up to 1.86 TeV and squark masses up to 1.59 TeV. The observed exclusions are lower than the expected exclusions because of the observed excess in the data.

7 Summary

The results of a search for general gauge-mediated supersymmetry breaking in proton-proton collisions with two photons and missing transverse momentum in the final state are reported. The analysis was performed using data corresponding to 35.9 fb^{-1} of integrated luminosity, recorded with the CMS detector in 2016 at a proton-proton center-of-mass energy of 13 TeV. An excess of events corresponding to 2.4 standard deviations is observed. Limits are deter-

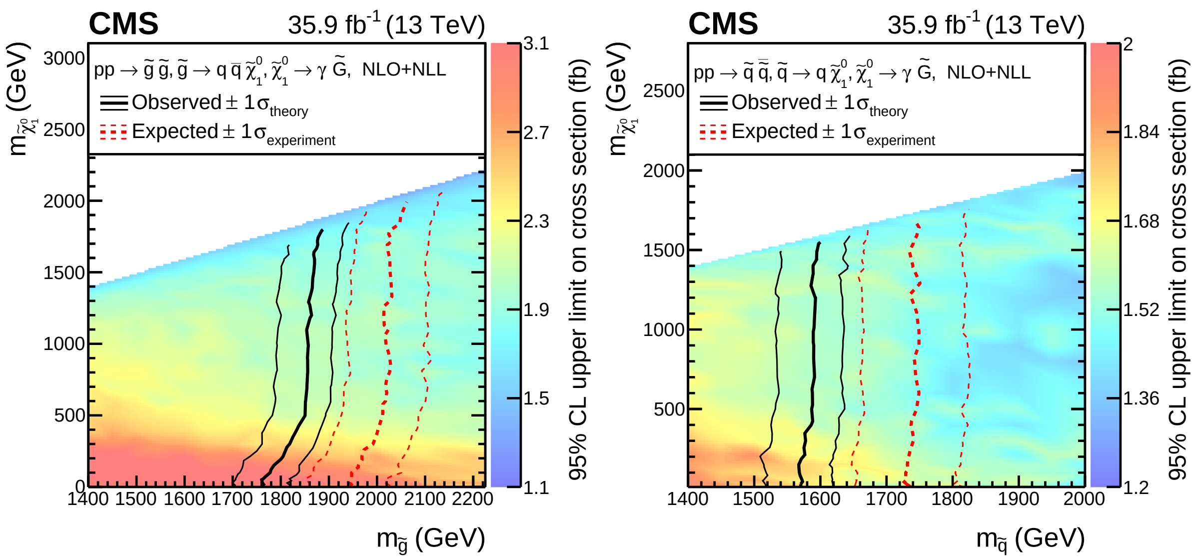


Figure 3: The 95% confidence level upper limits on the gluino (left) and squark (right) pair production cross sections as a function of gluino or squark and neutralino masses. The contours show the observed and expected exclusions assuming the NLO+NLL cross sections, with their one standard deviation uncertainties.

mined on the masses of supersymmetric particles in two simplified models using data-driven background estimation methods and NLO+NLL signal cross section calculations.

In both models, the next-to-lightest supersymmetric particle is the neutralino, which decays with a 100% branching fraction to a photon and a gravitino, the lightest supersymmetric particle. The first simplified model assumes gluino pair production, with each gluino decaying to a neutralino and quarks. The second simplified model assumes squark pair production, with each squark decaying to a quark and a neutralino. The expected limits on gluino and squark masses, for the respective models, are 2.02 and 1.74 TeV at 95% confidence level. This is an increase in sensitivity of more than 300 GeV for each model with respect to the analysis performed with 2.3 fb^{-1} of integrated luminosity collected using the CMS detector in 2015. The observed exclusions are for gluino masses less than 1.86 TeV and squark masses less than 1.59 TeV, where the difference between the expected and observed exclusions is driven by the excess observed in the data. The analysis described in this paper improves the observed limits by 210 GeV for gluino masses and 220 GeV for squark masses with respect to the previous CMS result.

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